In Situ, Three-Dimensional Flow Velocity Measurement

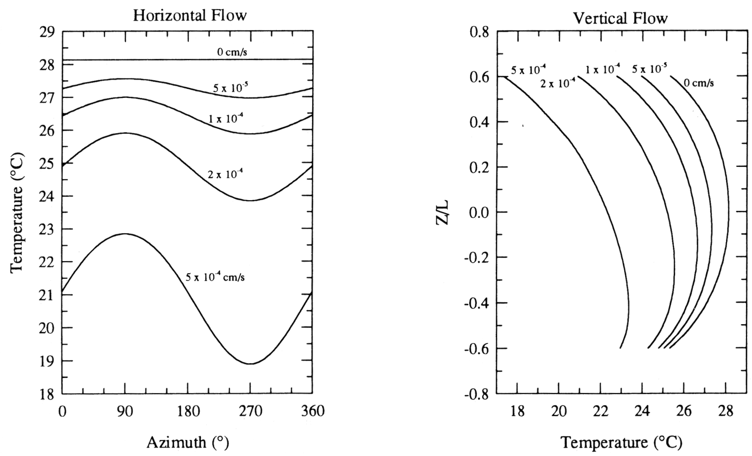
Need

Accurate information about the ground-water flow field is a key element in the solution of a wide range of waste disposal and contaminant remediation problems. Determination of the full 3-dimensional flow velocity vector using conventional technology requires multiple boreholes and detailed knowledge of the hydraulic conductivity distribution. Sandia National Laboratories has developed an *in situ* permeable flow sensor and associated analysis techniques that allows direct measurement of the 3-dimensional flow velocity vector in unconsolidated, saturated, porous media. This technology has been successfully tested at multiple field sites, and the sensor itself is now commercially available.

Description

The basic operating principle of this technology is to bury a thin (2-inch diameter), cylindrical heater in the subsurface at the point where ground-water velocity is to be measured. With uniform heat flux out of the cylinder, the temperature distribution on the surface of the cylinder varies as a function of the direction and magnitude of ground-water flow past the cylinder. In essence, relatively warm temperatures are observed on the downstream side of the probe and relatively cool temperatures are observed on the upstream side because some of the heat introduced into the formation by the heater is advected around the instrument past the tool. An array of 30 temperature sensors on the probe surface, each capable of measuring to within 0.01^0 C, provides the pattern of temperature variation on the probe surface. Analysis of this temperature distribution produces a direct determination of the 3-dimensional velocity vector that is characteristic of approximately one cubic meter of the subsurface. This technology is capable of measuring flow velocities in the range from 5×10^{-6} to 1×10^{-3} cm/second, depending on the thermal properties of the medium in which the probe is buried. Integrating this 3-dimensional velocity data with other geologic and hydrologic information is a key part of the analysis process.

An in situ permeable flow sensor being placed into the subsurface through a hollow stem auger.



Probe surface temperature as a function of azimuth for a probe buried in purely horizontal flow [left] and as a function of vertical position for a probe in a downwardly directed flow field [right].

Example Applications

The *in situ* permeable flow probe has been applied to a variety of field problems, including: monitoring of an air stripping / bioremediation experiment at the Savanah River Site in South Carolina; a study of the interaction between ground water and the Columbia River in Washington state; monitoring of the sinkhole possibly associated with a Strategic Petroleum Reserve Facility in Louisiana; and monitoring an in-well vapor stripping remediation project at Edwards Air Force Base in California. In all of these applications, data from the flow probe is analyzed in conjunction with other surface information to provide the technical basis for project decisions.

References

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